APPLICATION OF UREA SNCR
ON A TANGENTIALLY FIRED 84 MWe PULVERIZED COAL BOILER

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Abstract

As part of an overall compliance plan to reduce NOx emissions, Delmarva Power contracted with Research-Cottrell, Inc. in 1995 to install a urea-based Selective Non-Catalytic Reduction (SNCR) system on their Edge Moor Unit 3 (EM3) boiler. The unit is a tangentially fired pulverized coal (PC) boiler, nominally rated at 84 Megawatt (MWe).

Along with design engineering, equipment supply, and start-up and optimization, Research-Cottrell also supplied additional engineering services related to the SNCR system. Several unique features of the project included: 1) provision for future system expansion, 2) preliminary engineering modifications of existing CEMS to prevent pluggage due to ammonia slip, 3) development and implementation of a performance test plan, and 4) application of mechanically-attached pipe fittings.

Under Phase I of the 1990 Clean Air Act Amendments and as stipulated by Delaware law, the NOx emission limit was set at 0.38 lb/MMBTU. The baseline NOx for EM3 was 0.54 lb/MMBTU. In April of 1996, completion of system start-up and optimization showed that the required 30% reduction in NOx emissions was achieved with less than 15 ppm of ammonia slip. Further system optimization was subsequently performed and achieved a 35% reduction in predicted chemical consumption.

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Introduction

EM3 is a Combustion Engineering tangentially-fired, balanced draft boiler with a nominal rating of 84 MWe that was first placed in service in 1954. It is located on the western bank of the Delaware River in Wilmington, Delaware. The unit fires eastern bituminous coal as its primary fuel, but has the capability of firing natural gas and #6 oil as backup fuels. A boiler elevation drawing is shown in Figure 1.

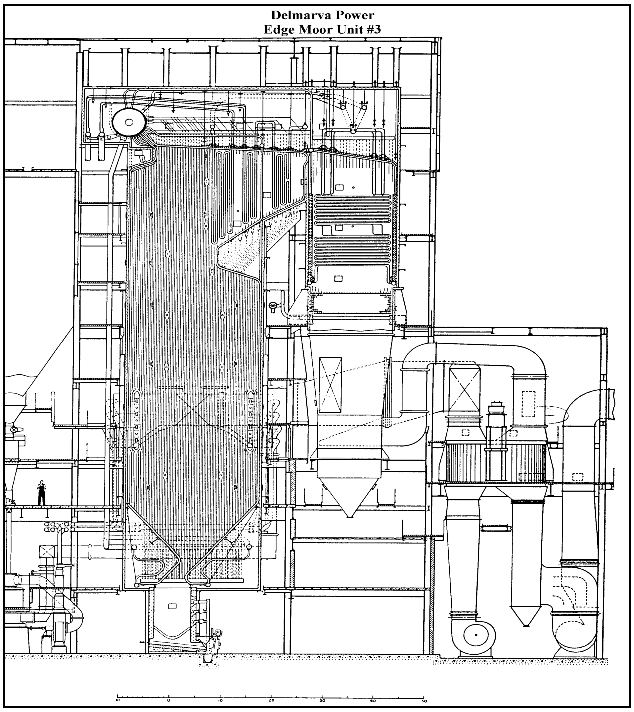

Figure 1

After evaluating possible NOx control technologies, Delmarva Power decided to install an SNCR system on EM3 to meet RACT requirements promulgated by the Delaware Department of Natural Resources & Environmental Control (DNREC). The system was also installed to evaluate the performance of the urea-based SNCR process in preparation for the tighter emission limits expected in Phase II and potential use on other boilers owned by Delmarva Power. Delmarva intends to operate the system only during the peak ozone season (summer months).

Urea-based SNCR is a post-combustion process that reduces NOx by injecting a controlled amount of an aqueous urea reagent into the specific temperature zones of the boiler. Once the urea evaporates and comes into contact with the NOx in the flue gas, a chemical reaction takes place that converts the NOx (mostly NO) into harmless by-products - nitrogen, water and carbon dioxide. Boiler regions must possess a temperature range of 1,600°F to 2,100°F for the reaction to successfully occur.

The design of an SNCR system takes into account several factors, including boiler conditions, process requirements and site specific constraints. Process performance is dependent primarily on NOx baseline, flue gas temperature, excess oxygen and carbon monoxide levels[1]. Residence time is also a controlling factor. Boiler conditions that impact SNCR design include fuel properties, load range, capacity factor, boiler control settings, furnace dimensions, and properties of the flue gas, such as temperature/velocity profiles and chemical constituents. All of these conditions are considered during the Process Modeling phase, which is a necessary pre-requisite to obtaining an effective design. In this step, a combined Chemical Kinetic (CK) and Computational Fluid Dynamics (CFD) model is used. The model incorporates specialized chemical reaction and droplet evaporation software routines. The SNCR equipment is designed with sufficient flexibility to permit fine tuning of the system during start-up and optimization.

SNCR System Design

Process Modeling

As a pre-requisite for final system design, temperature measurements were taken at various boiler depths and elevations. Simultaneous readings of NOx, CO and O_2 levels at some of these locations were also obtained. The resulting temperature profiles and emissions data were used in conjunction with CK and CFD modeling to analyze four cases:

Case 1: **84 MWe Firing Coal** - NOx Baseline = 0.59 lb/MMBTU, O_2 = 4.1 % by vol, CO = 100 ppmv

Case 2: **81 MWe Firing Coal and #6 Oil** - NOx Baseline = 0.61 lb/MMBTU, O_2 = 4.6 % vol,, CO = 140 ppmv

Case 3: **66 MWe Firing Coal** - NOx Baseline = 0.59 lb/MMBTU, O_2 = 6.3 % vol, CO = 80 ppmv

Case 4: **39 MWe Firing Coal** - NOx Baseline = 0.68 lb/MMBTU, O_2 = 7.1 % vol, CO = 40 ppmv

For each case, the target NOx was set at 0.38 lb/MMBTU and ammonia slip was limited to 15 ppmv. The results of the modeling effort provided a basis for selecting an injection scheme that was optimal for each of the four cases. Three levels or "zones" of injection were chosen. Each zone was located at a specified boiler elevation to enable the system to follow the required temperature window at different boiler load points.

Equipment Selection, Function and Layout

[1] Romero, C.E. and Ciarlante, V., "Sensitivity of the SNCR Process to Furnace Process Variables", *First Annual DOE Conference on SCR & SNCR*, May '97

The major system components, as shown in Figure 2, include: one Truck Unloading Station, one Reagent Storage Tank, one Circulation Module and Recirculation Loop, three Metering Modules, three Distribution Modules, one Air Compressor and fifteen Injectors. A 50% by weight urea solution is delivered by truck and loaded into the storage tank, which is insulated and heated by external electrical pads. At this concentration, the reagent must be kept at a temperature above 60°F to prevent crystallization into a solid state. Most of the heat required is supplied by an in-line heater, which is integral to the Circulation Module. A recirculation loop also helps to prevent no flow conditions and maintains the reagent in a well mixed state inside the storage tank. However, the primary function of the Circulation Module is to deliver the required urea for injection to the Metering Modules. At the Metering Modules, the urea is regulated and then diluted with water to allow greater coverage across the boiler. Two of the Metering Modules provide independent control of each injection zone and operate normally in manual or automatic mode; the third is on stand-by. The Distribution Modules regulate the flow of diluted urea and air to each injector. Flow rates and pressures are set manually during start-up. The injectors are dual fluid type, whereby low pressure service quality air (<100 psig), supplied by a dedicated air compressor, is used to atomize the diluted urea and cool the injectors. Zones 2 and 3 contain six and five wall-mounted injectors, respectively, and are intended for operation at mid and high boiler loads (Cases 1, 2 and 3). Zone 1 has four 'retractable' injectors for use at low load (Case 4). These injectors are automatically retracted from the boiler via a pneumatic mechanism during higher loads to protect and extend the life of the injectors. Several new boiler ports were added to accommodate insertion of the injectors. The Truck Unloading Station, Reagent Storage Tank and Circulation Module are located outdoors at grade, while all other equipment is located inside the building adjacent to the boiler. The location of the zones of injection is depicted in Figure 3.

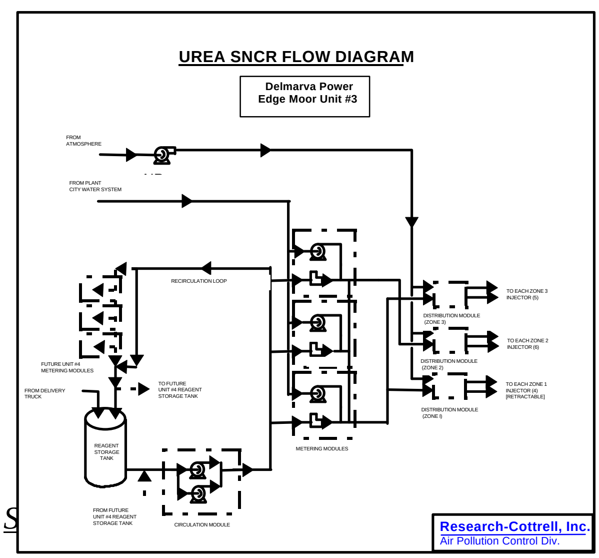

Figure 2

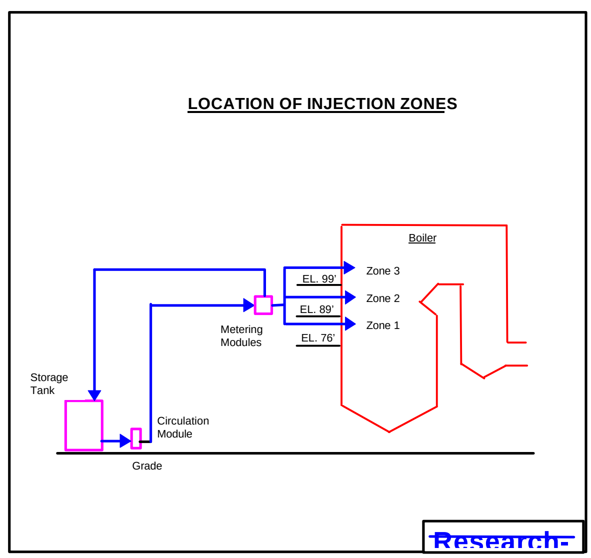

Figure 3

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The amount of ur[...] the injectors is regulated by means of a dc-d[...]ring pump, which receives a signal from a local control panel during manual mode or from the existing plant distributive control system (DCS) when the remote automatic mode is selected. Based on a feed forward signal, i.e., fuel and steam flow, the urea pumping rate is set to a pre-defined range of values to meet the required target NOx emission. A NOx signal from the continuous emissions monitoring system (CEMS) is used as a feedback signal in a proportional integral derivative (PID) loop to regulate pumping rate to maintain NOx at setpoint.

Project Schedule

Temperature mapping was performed in November, 1994 by taking gas temperature measurements at various elevations in the boiler. Process modeling, engineering services and supply of the SNCR equipment was contracted in March, 1995. Following a highly aggressive project schedule, the equipment was delivered to the plant in October, 1995. Installation occurred during a scheduled four week outage beginning in October and extending into November, 1995. Start-up was completed on schedule in April, 1996.

Unique Project Highlights

Delmarva Power comprehensively investigated low NOx combustion equipment strategies and decided, with approval from DNREC, that SNCR would be the most promising. After careful study, Delmarva Power selected Research-Cottrell for their ability to perform in an innovative and cost-effective manner. As a result, benefits of this contract were as follows:

> **Vendor Supplied Engineering Tasks** departing from its normal procedure of contracting a traditional A/E firm, Delmarva decided to use Research-Cottrell for several key engineering tasks related to the SNCR system, including location of the unloading station and storage tank (used old stack foundations), determination of power feed tie-ins, definition of conduit and cable runs, structural engineering, identification of suitable ammonia monitors, location of Research-Cottrell supplied equipment and interface points, and updating of existing Delmarva Power drawings. This unique approach for Delmarva provided substantial savings in engineering costs.
>
> **Future Design Preparations** - the existing design for EM3 provides tie-ins (Figure 2) for possible future use of SNCR on Edge Moor Unit 4 (EM4). The close proximity of EM4 to EM3 will allow both units to share some of the existing equipment, such as the Storage Tank and Circulation Module, thereby providing savings in capital cost.
>
> **Modifications of Existing CEMS** - in recognition of the possible plugging of CEMS sample probes by ammonia slip from the SNCR system, Research-Cottrell, working closely with its sister company, KVB (supplier of the CEMS system for this boiler), partially re-engineered the CEMS to assure proper operation in this situation. Delmarva has not yet installed the modifications. Results from further testing will determine whether these modifications are needed for EM3.

Performance Test Plan - to evaluate the impacts of the SNCR system on boiler operation, such as possible pluggage of downstream heat exchange surfaces and CEMS due to ammonium bisulfate formed from ammonia slip, flyash contamination due to ammonia slip and any reduction in unit heat rate, Delmarva independently initiated an on-going data gathering program. To aid them in this endeavor, Delmarva contracted with and used the expertise of Lehigh University's Energy Research Center (ERC) to develop a performance test plan.

Application of Victaulic Pressfit® Fittings - these mechanically-attached fittings were installed on all field interconnect air, water and urea piping to replace welded fittings. This change resulted in overall savings in construction costs of $25,000.

SNCR System Performance

As part of the start-up effort, the SNCR system was tested at the four cases identified earlier. For each case, a suitable chemical pumping rate was chosen based on process modeling results to achieve the desired NOx reduction and ammonia slip. Injection spray patterns and zone of injection, and urea flow was adjusted to minimize reagent consumption while simultaneously optimizing NOx reduction and minimizing ammonia slip. Figures 4, 5 and 6 show the results of the first system optimization for the low load, mid load and high load cases, respectively, while burning coal (a small proportion of landfill gas was also included). With higher values of Normalized Stochiometric Ratio (NSR), NOx reduction increased, as ammonia slip also increased. However, for all tested NSR's, the measured ammonia slip was less than 15 ppm. The results of this first optimization effort served as a starting base, until the system could be operated long enough to obtain more performance data.

It was decided to conduct a second SNCR system optimization. Delmarva contracted with the ERC of Lehigh University to develop, with Delmarva assistance, a SNCR performance test plan. The second optimization and SNCR performance test plan were jointly performed by Delmarva and the ERC during the summer of 1996. The tests performed concentrated primarily on reducing NOx to the required limit of 0.38 lb/MMBTU (30 to 45% reduction). The merits of multi-zone injection, where chemical flows were varied to Zones 2 and 3 at high load, were tested and are shown in Figures 7 and 8. After testing was completed, reagent consumption was reduced by 35%. Delmarva estimated the payback period to be less than 3 years based upon full load unit operation and SNCR operation during only the summer months.

Acknowledgments

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Delmarva Power - The 1995 Clean Air Compliance Project Team, led by Dan Skedzielewski and

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Research-Cottrell -	Project team led byR.P. Casill, and J.E.Staudt, engineering team led by S. Kozma and B.Patel, and start-up team led by P. Aa.

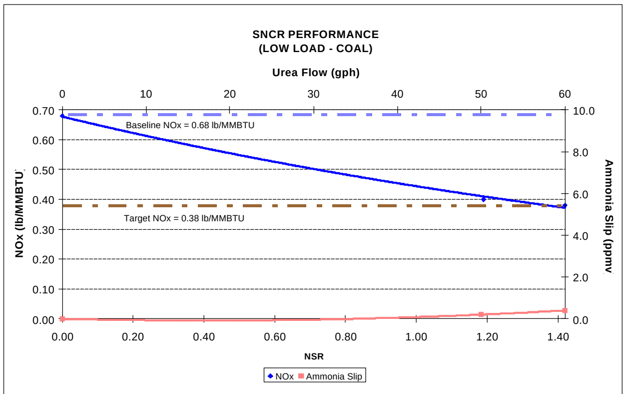

Figure 4

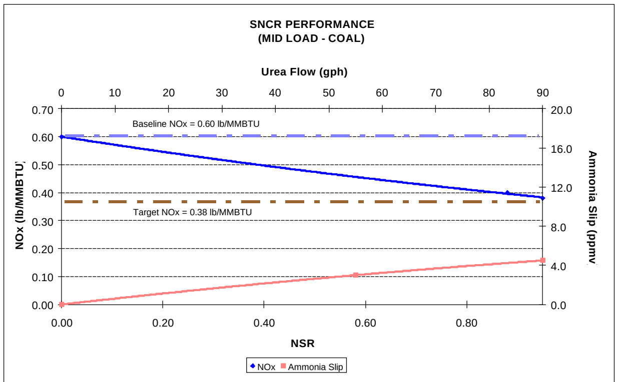

Figure 5

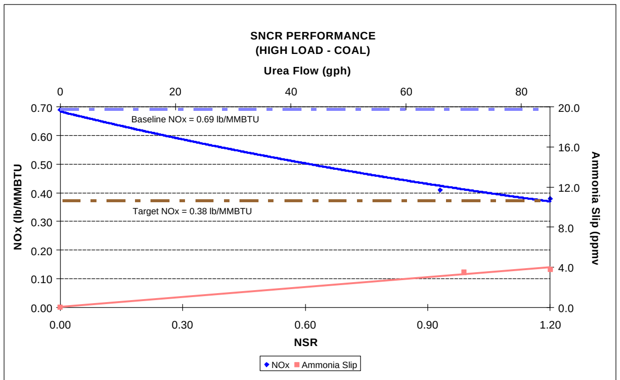

Figure 6

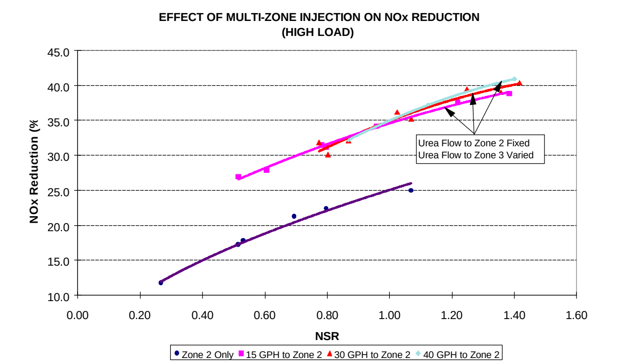

Figure 7

Source: D'Agostini, M. and Romero, C.E., Energy Research Center of Lehigh University, Final Report to Delmara Power entitled "SNCR Characterization for Full Load Operation at Edge Moor Unit 3", December, 1996

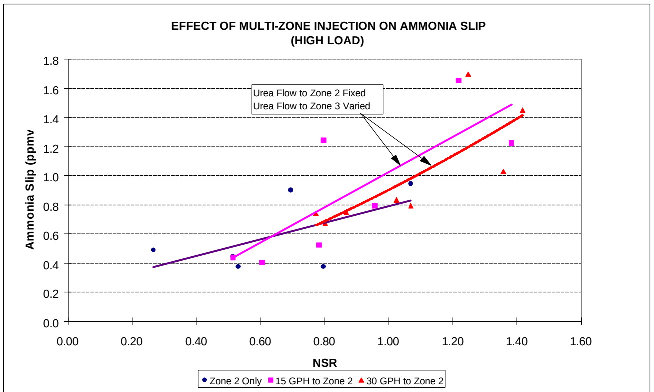

Figure 8

Source: D'Agostini, M. and Romero, C.E., Energy Research Center of Lehigh University, Final Report to Delmara Power entitled "SNCR Characterization for Full Load Operation at Edge Moor Unit 3", December, 1996